Patent Application of ALEKSANDR L. YUFA

for

METHOD AND DEVICE FOR COUNTING AND MEASURING PARTICLES

FIELD OF THE INVENTION

This invention relates to air and liquid quality and, more particularly, to devices and instruments for particle quantity counting and particle size measuring by light or laser beam ~~by light scattering.~~

BACKGROUND OF THE INVENTION

The methods and devices for determining quantity and size of the particles and small bodies are now well known, and it is also well known that powerful light or laser and optical system or mirror can be, and have been, heretofore used to achieve particle size and particle quantity measurements. Such devices ~~using light scattering~~ are well known and described in the articles: R.G.Knollenberg, B.Schuster--"Detection and Sizing of Small Particles in Open Cavity Gas Laser," Applied Optics, Vo.11, No.7, November 1972, pp.1515-1520; R.G.Knollenberg--"An Active Scattering Aerosol Spectrometer," Atmospheric Technology, No.2, June 1973, pp.80-81; Schehl, Ergun, Headrick--"Size Spectrometry of Aerosols Using Light Scattering from the Cavity of a Gas Laser," Review of Scientific Instruments, Vol. 44, No. 9, September 1973; R.G.Knollenberg--"Active Scattering Aerosol Spectrometry," National Bureau of Standards Special Publication, No.412, October 1974, pp.57-64; R.G.Knollenberg, R.E.Luehr--"Open Cavity Laser 'Active' Scattering Particle Spectrometry from 0.05 to 5.0 Microns," Fine Particles,

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Aerosol Generation Measurement, Sampling and Analysis, Academic Press, May 1975, pp.669-696; R.G.Knollenberg--"Three New Instruments for Cloud Physics Measurements: The 2-D Spectrometer, the Forward Scattering Spectrometer Probe, and the Active Scattering Aerosol Spectrometer", American Meteorological Society, International Conference on Cloud Physics, July 1976, pp. 554-561; R.G.Knollenberg --"The Use of Low Power Laser in Particle Size Spectrometry", Proceeding of the Society of Photo-Optical Instrumentation Engineers, Practical Applications of Low Power Lasers, Vo.92, August 1976, pp.137-152; Elterman--"Brewster Angle Light Trap," Applied Optics, Vol. 16, No. 9, September 1977; Marple--"The Aerodynamics Size Calibration of Optical Particle Counters by Inertial Impactors," Aerosol Measurement, 1979; Diehl, Smith, Sydor--"Analysis by Suspended Solids by Single-Particle Scattering," Applied Optics, Vol. 18, No. 10, May 1979; K.Suda--Review of Scientific Instruments, Vol. 51, No. 8, August 1980, pp.1049-1058; R.G.Knollenberg--"The Measurement of Particle Sizes Below 0.1 Micrometers", Journal of Environment Science, January-February, 1985, pp. 64-67; Peters--"20 Good Reasons to Use In Situ Particle Monitors", Semiconductor International, Nov. 1992, pp.52-57 and Busselman et al.--"In Situ Particle Monitoring in a Single Wafer Poly Silicon and Silicon Nitride Etch System", IEEE/SEMI Int'l Semiconductor Manufacturing Science Symposium, 1993, pp.20-26.

The reference in these articles is made to the devices and methods of particle measurement utilizing an open cavity laser. These nethods and devices use imaging systems, which are based

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on lens use, the same as it mentioned, for example, in U.S. Patent No. 4,140,395, U.S. Patent No.4,798,465 and in U.S. Patent No. 5,495,105 of the prior art.

The other devices mentioned in prior art (for example, U.S. Patent No. 4,606,636) use a non-divergent quadric reflector. Such devices use a paraboloidal sphere as mirror.

Yet in other prior art (for example, such as U.S. Patent No. 4,189,236, U.S. Patent No. 4,523,841, U.S. Patent No. 5,467,189 and U.S. Patent No. 5,515,164) we can find the devices (sensors) with ellipsoidal mirrors instead of the lens systems or non-divergent quadric mirrors.

All these devices, mentioned in the prior art above, use light scattering focalizing methods. Such methods are based on the collection of the scattered light. A light scattering occurs at the first focal point (focus) by particles in the laser beam. Considering stochastic dispersion of the scattered light, the devices, mentioned in the above prior art, use mirrors or optics. This is necessary for scattered light collecting and focalizing at the second focal point (focus), where a light detector is placed and intended for scattered light detection.

Another known method uses direct detection, as it mentioned in U.S. Patent No.5,085,500. By this method, the scattered light in such devices is detected by the light detectors directly with no scattered light collection.

As shown on Fig.1, related to the use of the optics, regarding the U.S. Patents No.4,140,395, No. 4,798,465, and No. 5,495,105, the scattered light 6 is collected by the optical system 10, which is presented by the lenses.

On Fig.2 is presented the device, using non-divergent quadric mirror, (U.S. Patent No. 4,606,636). From Fig.2 we see that the collection of the scattered light is provided by non-divergent quadric mirror 18.

The counting and measuring devices (sensors), mentioned in the U.S. Patents No. 4,189,236, No. 4,523,841, No. 5,467,189, and No. 5,471,299, using an ellipsoidal mirrors 17, are presented on simplified Fig.3.

On Fig.4 is presented the particle sensor by U.S. Patent No. 5,515,164, also using the ellipsoidal mirror for the scattered light collection. This sensor uses ~~especially~~ specially increased cross-section outlet area of the particle flow.

On Fig.5 is shown a simplified drawing of the device, using the direct detection method.

It is understood, that the methods and devices, mentioned of the prior art of the above, require the use of the scattered light collection means and systems (Figs.1-4) or very large spatial surface of the light detector or sufficient quantity of the light detectors (Fig.5). Such methods and/or devices need to include expensive means and systems. Also, the mentioned above methods and devices have a common deficiency, which is ~~contained in the~~ characterized by non-consideration of all scattered light plurality (for example, a scattered light 23 on Figs.1-5) and non-precise focalizing of the particle flow (for example, a scattered light 7 on Figs.1-5).

It is known, that integrated circuits (chips) and semiconductors have been produced in "clean rooms". The air in such "clean rooms" should be very well cleaned. The continuing tendencies of improvement in circuit integration and degree of microminiaturization require corresponding

improvements of the environment in "clean rooms" and efficiency of the measuring devices. And now, as known from prior art, the sensitivity of the counting and measuring devices should be at least as small as 0.1μm (Micron).

Thus, the unfocused and/or unconsidered (undetected) scattered light in the mentioned above devices of a prior art creates light background (light noises) inside such devices, creating thereby incorrectness of the resulting information about the measured environment. Additionally, such light noises limit the sensitivity of such devices.

OBJECT AND ADVANTAGES OF THE INVENTION

Accordingly, several objects and advantages of the present invention are to provide an improved method and device for counting and measuring particles.

It is another object of the invention to provide an improved method and device for increasing the precision of particle counting and measuring.

It is still another object of the invention to provide an improved method and device for increasing the efficiency of the measuring and counting process.

It is still further an object of the invention to provide an improved method and device for increasing the authenticity of the information about air or liquid composition.

It is yet another object of the invention to provide an improved method and device for decreasing light noises by the elimination of unfocused and/or unconsidered scattered light.

It is another further object of the invention to provide an improved method and device for increasing sensitivity of the particle size detection by the elimination of the scattered light collection.

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Still, further objects and advantages will become apparent from a consideration of the ensuing description accompanying drawings.

DESCRIPTION OF THE DRAWING

Fig.1 is a presentation of the scattered light collection by an optics in the prior art ~~devices~~.

Fig.2 is a presentation of the scattered light collection by a non-divergent quadric mirror in the prior art ~~devices~~.

Fig.3 is a presentation of the scattered light collection by an ellipsoidal mirror in the prior art ~~devices~~.

Fig.4 is a presentation of the scattered light collection by an ellipsoidal mirror with the especially increased inlet cross-sectional area of the particle flow in the prior art ~~devices~~.

Fig .5 is a presentation of the scattered light direct detection method in the prior art ~~devices~~.

Fig.6 is a presentation of the simplified drawing of the light detecting system of the improved device with the divided particle flow tubular means ~~method and device for airborne particles~~.

Fig.7 is presentation of the simplified drawing of the light detecting system of the improved device with non-divided particle flow tubular means ~~method and device for liquid particles (contaminations)~~.

Fig.8 is a presentation of the block diagram of an improved device.

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~~Fig.9 is a presentation of the block-diagram of the first variant of the analog-digital subsystem of an improved device.~~

Fig.~~10~~ 9 is a presentation of the block-diagram ~~of the second variant~~ of the analog-digital subsystem of an improved device.

Fig.~~11~~ 10 is a presentation of the signal timing-diagram.

Fig.~~12~~ 11 is a representation of the block-diagram of an improved device with the remote light beam source.

SUMMARY OF THE INVENTION

The invention provides a method and device, having a high sensitivity and a precision of counting and measuring particles, wherein ~~achieving~~ a particle size sensitivity achieves at least as small as 0.1µm. An improved method of counting and measuring particles forms direct detection processes, eliminating the light scattering detection principles. An improved device, realizing the improved direct detection method, includes a light detecting system and a processing system, including an analog-digital subsystem and a control subsystem. A light or laser beam intersects a particle flow inside a light detecting system in the light detection means area. The light detection means is placed on the light beam axis. The signals detected by light detection means through an analog-digital subsystem follow to a processing system for ~~processing of the~~ signal~~s~~ processing and ~~displaying~~ displaying information. The improved method and device provide the direct detection of the particles and ~~amplitude or~~ timing processing of the detected signals.

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B3 ~~By an improved method, the improved amplitude processing of the detected signals is pro-~~ vided by comparison of reference voltage, determined by appropriate size of the particle, with the amplified detected signal, relative to the decreased intensity of the light beam by an obstruction created by the particle, flowing through the light beam. By an improved method, the improved timing processing of the detected signals is provided by strobing the digital pulses created from the amplified detected signals, having the different durations created by different size particles, ~~intersecting the light beam.~~

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Here the description of an improved method and device will be done in statics (as if the components of the improved device are suspended in the space) with description of their relative locations and connections to each other. The description of the improved processes and functional operations of an improved device will be done hereafter.

B Referring to Figs.6, 7, ~~8~~ a light detecting system 11 includes a chamber 12, a light beam axis 2 (a laser beam can be used), a particle flow along axis 3, a light detection means 4 and a particle flow tubular means 26. For example the ~~The~~ particle flow tubular (capillary) means 26, intended for airborne particles passage, can be divided ~~is~~ (interrupted) in the light detection means 4 area B4 (see Fig.6). A chamber 12 of the light detecting system 11 has a black flat (rough) inside coating, absorbing possible reflected light and eliminating thereby possible light background (light noises).

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On Fig.8 is shown a simplified presentation ~~the block-diagram~~ of an improved device, including a light detecting system 11, connected to an analog-digital subsystem 14 of a processing system 27. The analog-digital subsystem 14 is by a multiplexed bus 25 connected to a control subsystem 13 of a processing system 27. The control subsystem 13 includes a microprocessor subsystem 20 and a terminal means 21.

~~Referring to Fig.9, an analog-digital subsystem, regarding amplitude method processing of the detected light signals, includes an amplifying means 15, connected to a comparison means 16, which is connected to a reference voltage means 19. A comparison means 16 is connected to an analog-digital converting means 22.~~

On Fig. ~~10~~ 9 is presented an analog-digital subsystem, realizing a time ~~method~~ processing of the detected light signals. Mentioned analog-digital subsystem comprises an amplifying means 15, connected to a pulse forming means 24.

Fig. ~~11~~ 10 presents a timing diagram of the signal processing. On this figure τ_i represents a duration of the pulses, where i = 1, 2, 3, ...

On Fig. ~~12~~ 11 is presented a structure of an improved device with a remote light beam source. This device comprises a remote light beam source 28, connected by a fiber optic connecting means 29 to a light detecting system 11, which is electrically connected to a processing system 27, including a microprocessor subsystem 20 and a terminal means 21.

An improved device operates as follows. The light or laser beam along axis 2 intersects a particle flow along axis 3 within the particle monitoring region in the area of a light detection mean 4, placed on a light beam axis 2, as

shown on Figs.6, 7. When the particles of the particle flow intersect the light beam, the intensity of the light beam on the light detection means 4 will be less than at the time when the particles are missing, because the presence of a particle in the light beam is an obstruction for the light in the direction ~~obstructs the light~~ to the light detection means 4. B8

B Insert B8

The signals, detected by the light detection means 4, current signal ~~(see Fig.11a)~~ follow to the amplifying means 15 of the analog-digital subsystem 14 (Fig. 9) of a processing system 27 of an improved device (see Fig.8). ~~As shown on Figs.9, 10, these signals from light detection means 4 of the light detecting means 11 follow to the amplifying means 15.~~

B B B Insert B9

~~An improved method makes possible an amplitude processing of the detected signals (see Figs.9, 11) or a timing processing of the detected signals (see Figs.10, 11).~~ B9

~~On Fig.9 is shown the block-diagram of the analog-digital subsystem 14 from Fig.8, regarding the amplitude processing method. Referring to Fig.9, the signals amplified by the amplifying means 15 (Fig.11b), follow to a comparison means 16, to which also follows the appropriate reference voltages from a reference voltage means 19. The reference voltages are determined by appropriate sizes of the particles. The signals from the comparison means 16 follow to an analog-digital converting means 22.~~

B Insert B10 + B11

Referring to Fig. ~~10~~ 9, the signals amplified by the amplifying means 15 ~~(Fig.11b)~~ follow to the pulse forming means 24, which B10 forms the digital form pulses ~~(Fig.11c)~~ B11 ~~from the analog signals of the amplifying means 15~~, The pulse forming means 24 also comprises an internal interface means (not

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shown) for comunication by multiplexed bus 25 (or by a data bus and an address bus, which are not shown).

Referring again to Fig.8 and considering Fig~~s~~.9~~, 10~~, the signals from the analog-digital subsystem 14 follow by a multiplexed bus 25 to the control subsystem 13. For the timing ~~time~~ processing method, mentioned above, the signals (Fig.10c) from the analog-digital subsystem 14 are strobed by the strobe pulses (see Fig.10d) in the microprocessor subsystem 20 of the control subsystem 13. The ~~signals~~ (Fig.10e) processed by microprocessor subsystem 20 have different durations τ_i. These durations are related to the different sizes of particles, which create different obstructions of the light beam. The higher the frequency of the strobe pulses, the higher precision and ~~the sensitivity~~ of the improved device:

$$S = f\,(F_P) \qquad [1]$$

and

$$S \rightarrow \infty \Big|_{F_P \rightarrow \infty}\,, \qquad [2]$$

where S - a sensitivity;

f - a functional symbol (a function);

F_P - a strobe pulses frequency.

The microprocessor subsystem 20 is also connected by the multiplexed bus 25 to a terminal means 21, which can include a display means, a printing means, a compact disk ~~disc~~ (CD) means~~, a~~.

~~subsystem 14 and by multiplexed bus 25 to the microprocessor subsystem 20.~~

Referring to Fig. ~~12~~ 11, the light beam or laser beam is transferred from a remote light beam source (or remote laser ~~beam source~~) 28 to the chamber 12 (see Figs.6, 7) of a light detecting system 11 by a fiber optic connecting means 29.

CONCLUSION, RAMIFICATION AND SCOPE

Accordingly the reader will see that, according to the invention, I have provided a precise and effective methods and devices ~~device~~, which provide~~s~~ counting and measuring of all particles of the assayed air (gas) or liquid. An improved method and device provide authenticity of the real quantity and size of the particles in the assayed mixture of air, gas or liquid, because all particle plurality is considered. Also the improved method and device provide correctness of the resulting information, because the light noise (light background) inside ~~an~~ of improved device is eliminated.

While the above description contains many specificities, these should not construed as limitations on the scope of the invention, but as exemplification of the presently-preferred embodiments thereof. Many other ramifications are possible within the teaching of the invention. For example, an improved method and device provide authentic counting and measuring of particles, because very precise focusing of the mirrors or optics is not required. The procedure of periodical calibration is much easier for an improved timing ~~for improved amplitude~~ processing of the detected signals, because an improved method and device does not require the consideration of the light background, created by

~~tion is much easier for improved amplitude processing of the detected signals, because an improved method and device does not require the consideration of the light background (created by~~ non-focused ~~unfocused~~ and/or unconsidered scattered light, as it presents in the some known prior art, mentioned above~~)~~. The improved timing processing of the detected signals provides unlimited sensitivity of the improved device and eliminates necessity of the periodical calibration by manufacturer. Also an improved device uses a single small light detector.

Thus, the scope of the invention should be determined by the appended claims and their legal equivalents, and not by examples given.